Norwegian experience with development of Benefit/Cost Analysis tools for mitigation measures against geohazards

Nils Roar Sælthun

Professor at UNIS

Representing Norwegian Water Resources and Energy Directorate

Department for Landslides, Floods, and River Management

Floods

Debris flow

Landslides

Snow avalanches

Rock fall

Contents

- Principles for benefit-cost analysis in geohazard mitigation
- The implementation at NVE
- How to handle climate change effects
- Status and experiences

Geohazards, administrative responsibilities

- Roads: Norwegian Public Roads Administration
- Railroads: Norwegian National Rail Administration
- Buildings:
  - Locally: The municipalities
  - Centrally: Norwegian Water Resources and Energy Administration (NVE)

Common applied research project 2012-2015:

NIFS: Natural hazards, Infrastrukture, Floods, landSlides

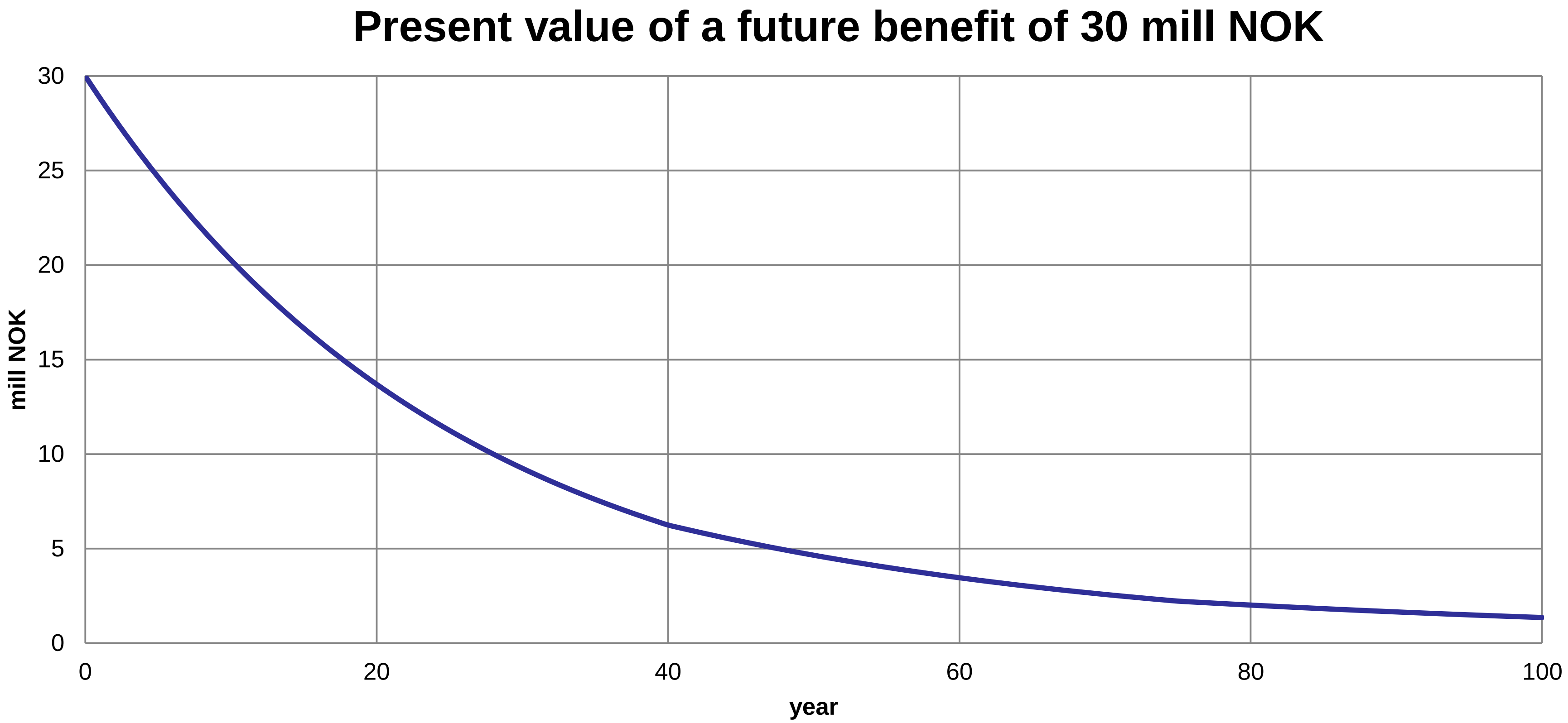
Overarching principle

- For all public investments it is required that they give a net benefit to society
- The accounting should include both economic cost and benefits, and intangibles
- This also applies to mitigation measures against geohazards
- It is commonly done by Benefit-Cost Analysis (BCA), or assessment of net benefit

Present value and discount rate

- In benefit-cost analysis all costs and benfits are referred to a common time frame, usually present value.
- Expected future benefits and cost are depreciated to present value by a set discount rate
- The discount rate for public investments is set by the Ministry of Finance, and is a powerful political tool
- It is presently set to 4% for the first 40 years, then 3% til 75 years, 2% after this

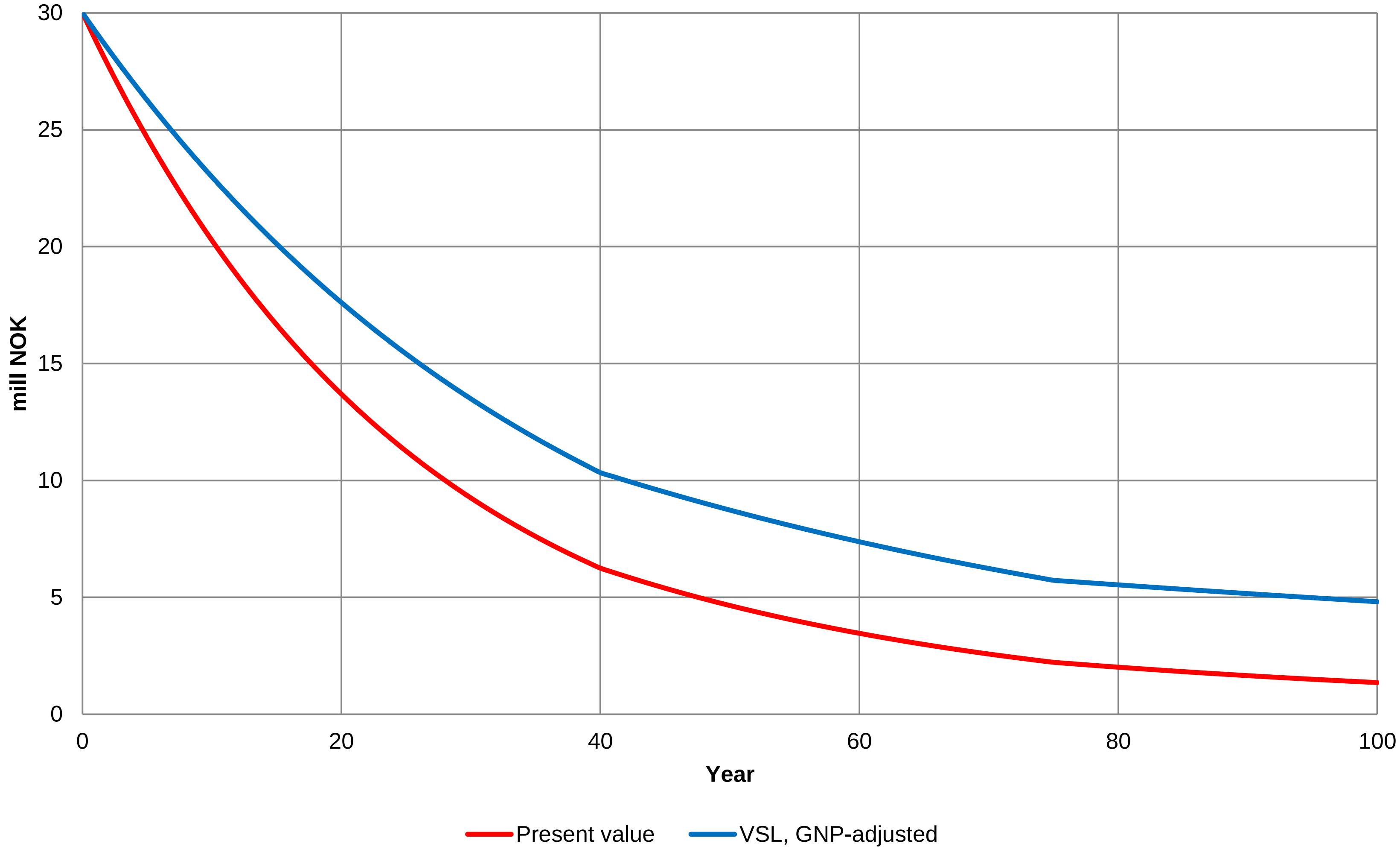
Discounting



Value of human life

- Value of a human life (saved) in the sense «Value of a statistical life» – VSL is set by the Ministry of Finance to 30 mill NOK, with a 2012 datum
- Applying this moves lifes fromintangibles to the economic benefit-cost analysis
- There has been a discussion in Norway whether future lives saved (or lost) should be discounted to a present vaue or not
- Most economists are in consensus that also lives should be discounted
- VSL is however upscaled with the expected growth in gross national product per capita, presently set to 1.3% p.a

Present value of VSL, with and without adjustment for GNP



Benefit-Cost Analysis at NVE

- NVE has had a tool for BCA since 2000. The original tool was limited to flood mitigation, and had a focus on agricultural areas.
- An upgraded tool was established in 2015, and is now under operational testing
  - It covers both floods and landslides
  - Includes VSL calculations
  - To the extent possible it is based on standardized prices and vulnerability factors
  - Intangibles – environment, recreational use, landscape, cultural heritage etc are only handled verbally. No scoring system (yet)
  - Analysis period is 40 or 80 years, for most projects 80

Types of hazards covered

- Floods in large rivers
- Debris flows and floods in steep rivers
- Rock fall
- Rock- and landslides
- Quick clay landslides
- Snow avalanches
- Slush avalanches
- River erosion events

Benefit-Cost tool at NVE

- Distinguishes between recurring events (for instance floods) and non-recurring (for instance quick clay slides)
- Typical damage assessment for a given event:

  $$D = U \cdot A \cdot V \cdot S$$

  where

  D is the total damage

  U is a unit price for replacement/full recovery

  A is a multiplier – for instance number of objects in the exposed area

  V is the vulnerability, between 0 and 1, 1 denotes total destruction

  S is the «hit probability»

- This is weighted by the probability of the event and discounted to present value
- Implemented in Excel

Objects included

- Objects/elements included in the benefit analysis are:
  - Buildings
  - Loss of life
  - Crop loss in agriculture
  - Total loss of agricultural land
  - Damage on parks and constructed recreational areas
  - Infrastruktur damage; roads, railways, and powergrid
  - Increased transport length due to road closure
  - Damage on parked cars
  - Mobilisation and immediate damage limitation
  - Removal of condemnd buildings
  - House rent during renovation/rebuilding period

Objects not included

- Objects/elements presently not include
  - Damage to private gardens
  - Forest damage
  - Stoppage costs for industry and trade
  - Stoppage costs caused by power outing
  - Loss of life outside buildings

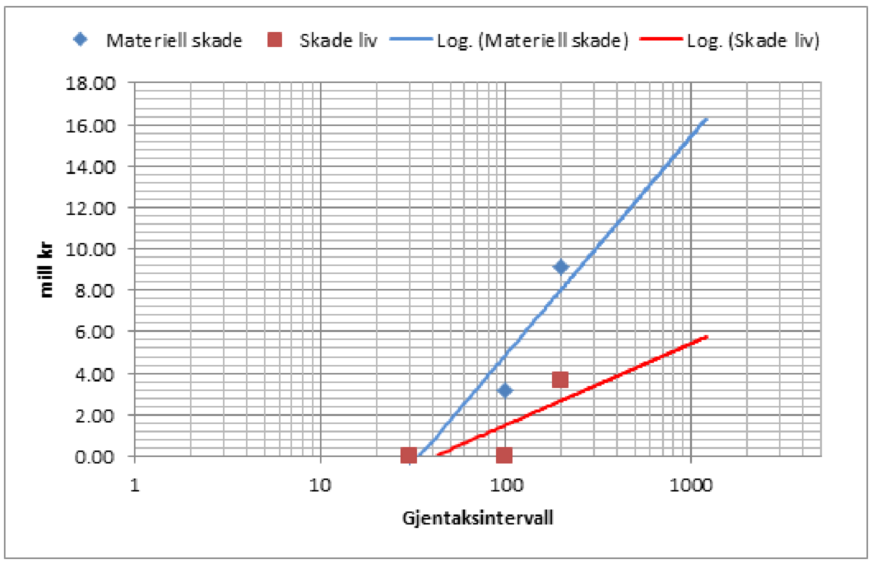
Frequency distribution, abated and unabated risk

Recurring event

Flomskred

Frekvensfunksjon skade:

	Gjentaks-intervall År	Materiell skade mill kr	Skade liv mill kr	Total skade mill. kr
Begynnende skade	30	0.00	0.00	0.00
Skadeprofil 1	100	3.21	0.00	3.21
Skadeprofil 2	200	9.14	3.64	12.78
Sikringsnvå:	200			

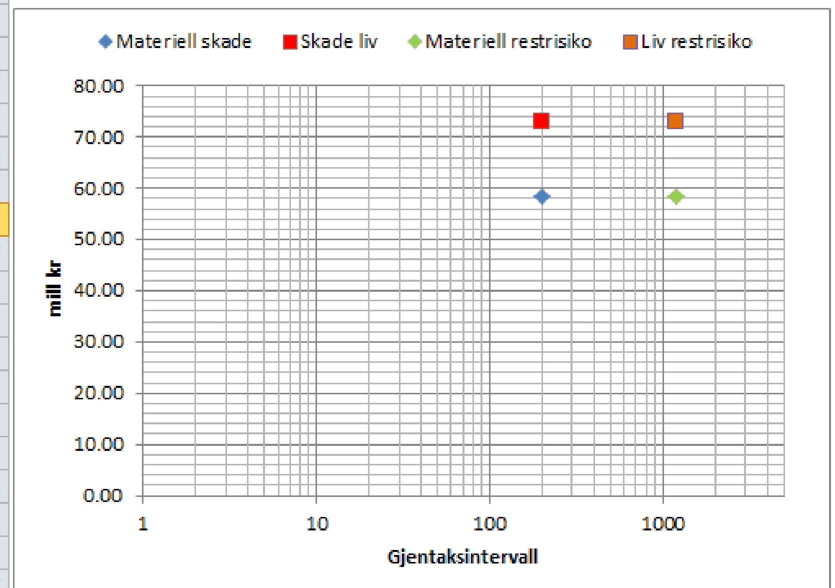


Non-recurring event

Leirskred

Skade

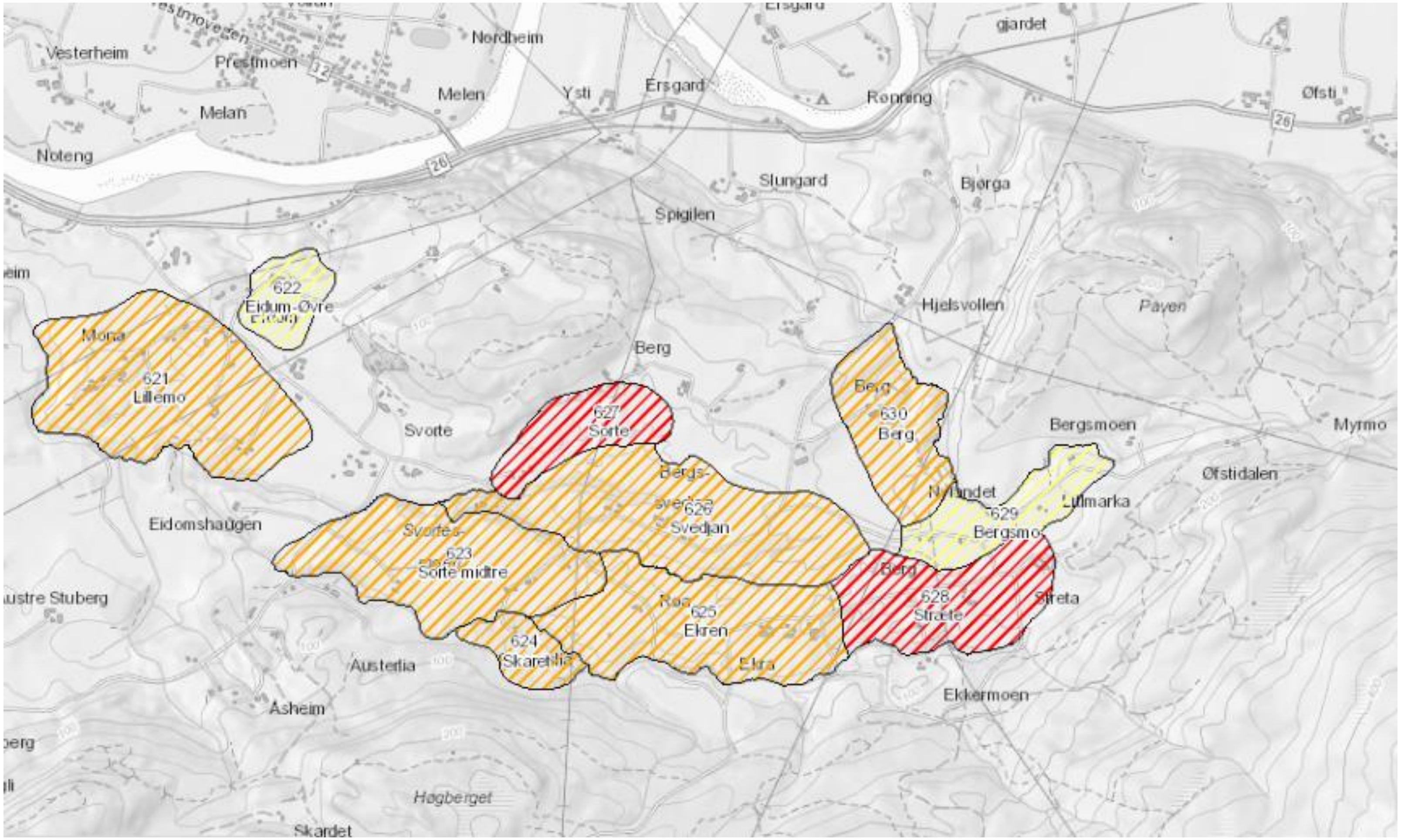
	Gjentaks-intervall År	Materiell skade mill kr	Skade liv mill kr	Total skade mill. kr
Skadeprofil 1	200	58.51	72.85	131.36
Restrisiko	1200	58.51	72.85	131.36



Challenges I – information on probability

- Probability of future events is necessesary for formal benefit-cost analysis.
- Available mapping of probability is very varying between event types:
  - Floods in large rivers: Good where flood zone maps have been produced. National coverage by Preliminary Flood Risk Assessment (PFRA) maps, but these do not give probabilities
  - Debris flows and floods in steep rivers, rock fall, rock- and landslides, avalanches: Danger zone maps with probabilities in some exposed communities, otherwise only at the "awareness" –level (comparable to PFRA concept)
  - Quick clay landslides: Good coverage, but no probabilities, only relative scoring – only intended for prioritization between quick clay mitigation measures
  - River erosion events: Very little done

Clay slide danger zones mapping



Source: NVEatlas http://atlas.nve.no

Challenges II – changing probabilities

- In most statistical analyses we assume that the past describes present and future conditions
- In reality the probabilities for disasterous events are continously changing:
  - Climate variability and antropogeneous climate change
  - Land use changes
  - Terrain manipulations
  - Forestry/forest regrowth
  - Access roads, forestry and agriculture

Challenges III – statistics on vulnerability

- In reality we have far to little information on many aspects of vulnerability, for instance:
  - average relationship between flood water level in a building and the damage
  - probability of being killed if you are inside a house being hit by an avalanche
- Such data has niot been collected systematically in Norway

Considering climate change

NVE’s climate change strategy 2015-2019 gives the following guidance prtinent to mitigation measures against geohazards and benefit-cost analysis:

- «For measures and decisions with long liftetime it should be considered whether they should be dimensioned to endure/withstand the expoected climate changes over the lifetime, or be dimensioned according to the present climate but prepared for reinforcements/reconstructions
- «In areas where regional climate change scenarios inidicate an increase of the flood peak (200 year flood) of more than 20% the coming 20 to 100 years, dimensioning of mitigation measures and benefit-cost analysis should be based on this information.»

NVE-rapport 2011:5
«Hydrological projections for floods in Norway under a future climate»

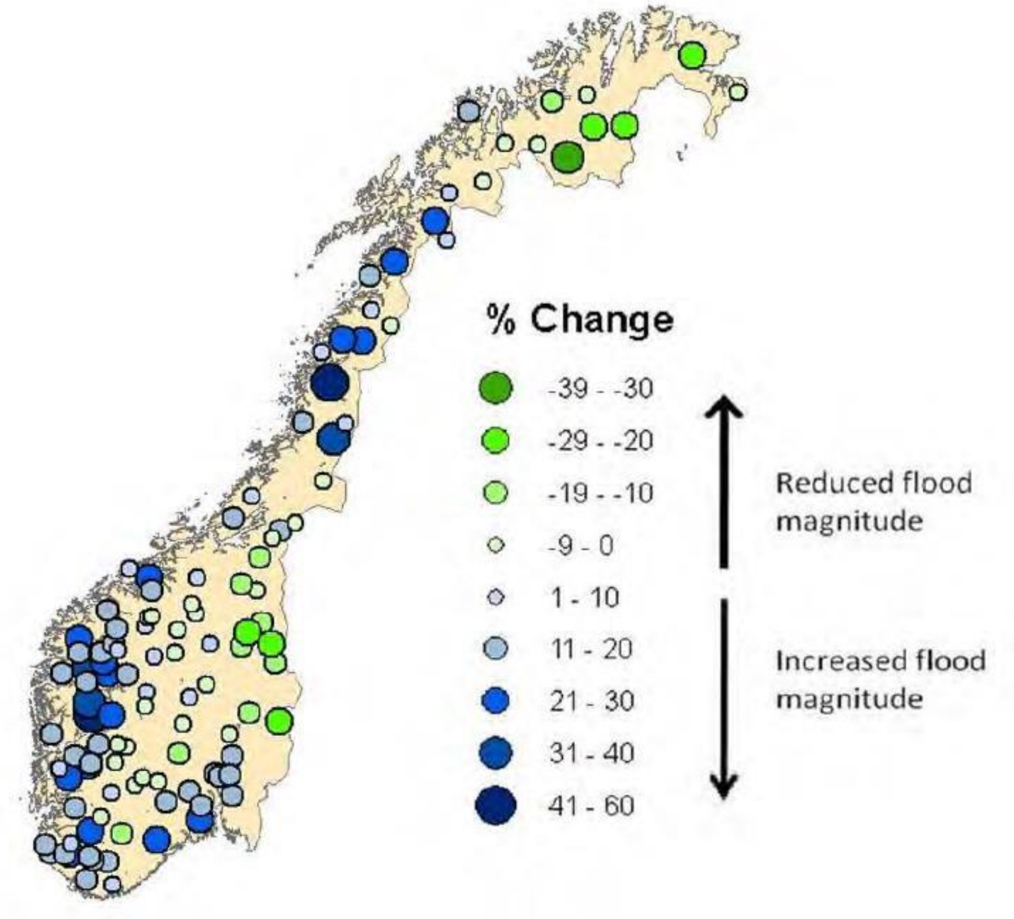


Figure 5.6 Projected percentage changes in the 200-year flood between the 1961-1990 reference period and the 2021-2050 future period, based on the median of the ensemble of hydrological projections. Green indicates a reduced flood magnitude and blue indicates an increase in flood magnitude.

Dramatic changes in flood frequencies

- Data from the Norwegian regional flood frequency analysis:

	Q5/QM	Q10/QM	Q20/QM	Q50/QM	Q100/QM	Q200/QM	Q500/QM	Q1000/QM
H1	1.3	1.6	1.8	2.2	2.5	2.8	3.2	3.5
H2	1.3	1.6	2.0	2.4	2.7	3.0	3.6	3.9
H3	1.3	1.7	2.0	2.6	3.0	3.4	4.2	4.7
Middelv.	1.3	1.6	1.9	2.4	2.7	3.1	3.7	4.0
+20 %	1.6	2.0	2.3	2.9	3.3	3.7	4.4	4.8
+40 %	1.8	2.3	2.7	3.4	3.8	4.3	5.1	5.6

	Q5/QM	Q10/QM	Q20/QM	Q50/QM	Q100/QM	Q200/QM	Q500/QM	Q1000/QM
H1	1.3	1.6	1.8	2.2	2.5	2.8	3.2	3.5
H2	1.3	1.6	2.0	2.4	2.7	3.0	3.6	3.9
H3	1.3	1.7	2.0	2.6	3.0	3.4	4.2	4.7
Middelv.	1.3	1.6	1.9	2.4	2.7	3.1	3.7	4.0
+20 %	1.6	2.0	2.3	2.9	3.3	3.7	4.4	4.8
+40 %	1.8	2.3	2.7	3.4	3.8	4.3	5.1	5.6

Handling changed flood probabilities in BCA

- The BCA tool is based on constant probabilities.
- Possible ways to handle increased flood probabilities

  0: Neglect future increase.

  Result: Underestimated benefit-cost ratio; protection level will detoriate

  1: Adjust damage profiles and dimension the measures for the expected situation at the end of the liftetime of the project

  Result: Underestimated benefit-cost ratio; protection level higher than required for most of the liftetime

  2: Adjust damage profiles and dimension the measures for the expected situation after one third of the liftetime of the project

  Result: «Correct» benefit-cost ratio; protection level varying from higher to lower than required through the lifetime

Experiences

- In principle NVE has been using BCA in geohazards management since year 2000
  - In practice it has been very limited use of the tool.
  - The reasons have not been thoroughly investigated, but the main reasons seems to be
    - Too open for subjective choices
    - High need for input data
    - Focus changed from agricultural land to built up areas, and the tool was not tailormade for that
    - Methodological weaknesses

Experiences

- The present tool was finalized at the end of 2015, and has been introduced to the operational staff by hands-on training first half of 2016.
  - Well received
  - Good documentation of the the decision process
  - Is used as an operational test dusring this years planning process
  - The judges are still out on whether the tool can be used on prioritation across geohazard types, for instance between measures against floods and measures against landslides

https://www.youtube.com/watch?v=tEe9PuQpB64